

(1) *Engine speed for variable-speed engines.* For variable-speed engines, normalized speed may be expressed as a percentage between idle speed and maximum test speed, f_{test} , or speed may be expressed by referring to a defined speed by name, such as warm idle, "intermediate speed," or "A," "B," or "C" speed. Section 1065.610 describes how to transform these normalized values into a sequence of reference speeds, f_{ref} . Note that the cycle-validation criteria in § 1065.514 allow an engine to govern itself at its in-use idle speed. This allowance permits you to test engines with enhanced-idle devices and to simulate the effects of transmissions such as automatic transmissions.

(2) *Engine torque for variable-speed engines.* For variable-speed engines, normalized torque is expressed as a percentage of the mapped torque at the corresponding reference speed. Section 1065.610 describes how to transform normalized torques into a sequence of reference torques, T_{ref} . Section 1065.610 also describes under what conditions you may command T_{ref} greater than the reference torque you calculated from a normalized duty cycle. This provision permits you to command T_{ref} values representing curb-idle transmission torque (CITT).

(3) *Engine torque for constant-speed engines.* For constant-speed engines, normalized torque is expressed as a percentage of maximum test torque, T_{test} . Section 1065.610 describes how to transform normalized torques into a sequence of reference torques, T_{ref} . Section 1065.610 also describes under what conditions you may command T_{ref} greater than 0 N·m when a normalized duty cycle specifies a 0% torque command.

(4) *Engine power.* For all engines, normalized power is expressed as a percentage of mapped power at maximum test speed, f_{test} . Section 1065.610 describes how to transform these normalized values into a sequence of reference powers, P_{ref} . You may convert these reference powers to reference speeds and torques for operator demand and dynamometer control.

(c) For variable-speed engines, command reference speeds and torques sequentially to perform a duty cycle.

Issue speed and torque commands at a frequency of at least 5 Hz for transient cycles and at least 1 Hz for steady-state cycles (i.e., discrete-mode and ramped-modal). For transient cycles, linearly interpolate between the 1 Hz reference values specified in the standard-setting part to determine the 5 Hz reference speeds and torques. During an emission test, record the 1 Hz mean values of the reference speeds and torques and the feedback speeds and torques. Use these recorded values to calculate cycle-validation statistics and total work.

(d) For constant-speed engines, operate the engine with the same production governor you used to map the engine in § 1065.525 or simulate the in-use operation of a governor the same way you simulated it to map the engine in § 1065.525. Command reference torque values sequentially to perform a duty cycle. Issue torque commands at a frequency of at least 5 Hz for transient cycles and at least 1 Hz for steady-state cycles (i.e., discrete-mode, ramped-modal). For transient cycles, linearly interpolate between the 1 Hz reference values specified in the standard-setting part to determine the 5 Hz reference torque values. During an emission test, record the 1 Hz mean values of the reference torques and the feedback speeds and torques. Use these recorded values to calculate cycle-validation statistics and total work.

(e) You may perform practice duty cycles with the test engine to optimize operator demand and dynamometer controls to meet the cycle-validation criteria specified in § 1065.514.

§ 1065.514 Cycle-validation criteria.

This section describes how to determine if the engine's operation during the test adequately matched the reference duty cycle. This section applies only to speed, torque, and power from the engine's primary output shaft. Other work inputs and outputs are not subject to cycle-validation criteria. For any data required in this section, use the duty cycle reference and feedback values that you recorded during a test interval.

(a) *Testing performed by EPA.* Our tests must meet the specifications of paragraph (g) of this section, unless we

determine that failing to meet the specifications is related to engine performance rather than to shortcomings of the dynamometer or other laboratory equipment.

(b) *Testing performed by manufacturers.* Emission tests that meet the specifications of paragraph (g) of this section satisfy the standard-setting part's requirements for duty cycles. You may ask to use a dynamometer or other laboratory equipment that cannot meet those specifications. We will approve your request as long as using the alternate equipment does not affect your ability to show compliance with the applicable emission standards.

(c) *Time-alignment.* Because time lag between feedback values and the reference values may bias cycle-validation results, you may advance or delay the entire sequence of feedback engine speed and torque pairs to synchronize them with the reference sequence.

(d) *Calculating work.* Before calculating work values, omit any points recorded during engine cranking and starting. Cranking and starting includes any time when an engine starter is engaged, any time when the engine is motored with a dynamometer for the sole purpose of starting the engine, and any time during operation before reaching idle speed. See § 1065.525(a) and (b) for more information about engine cranking. After omitting points recorded during engine cranking and starting, but before omitting any points under paragraph (e) of this section, calculate total work, W , based on the feedback values and reference work, W_{ref} , based on the reference values, as described in § 1065.650.

(e) *Omitting additional points.* Besides engine cranking, you may omit additional points from cycle-validation statistics as described in the following table:

TABLE 1 OF § 1065.514—PERMISSIBLE CRITERIA FOR OMITTING POINTS FROM DUTY-CYCLE REGRESSION STATISTICS

When operator demand is at its . . .	you may omit. . .	if. . .
For reference duty cycles that are specified in terms of speed and torque (f_{nref} , T_{ref}).		
minimum	power and torque	$T_{ref} < 0\%$ (motoring).
minimum	power and speed	$f_{nref} = 0\%$ (idle) and $T_{ref} = 0\%$ (idle) and $T_{ref} - (2\% \cdot T_{max mapped}) < T < T_{ref} + (2\% \cdot T_{max mapped})$.
minimum	power and either torque or speed	$f_n > f_{nref}$ or $T > T_{ref}$ but not if $f_n > f_{nref}$ and $T > T_{ref}$.
maximum	power and either torque or speed	$f_n < f_{nref}$ or $T < T_{ref}$ but not if $f_n < f_{nref}$ and $T < T_{ref}$.
For reference duty cycles that are specified in terms of speed and power (f_{nref} , P_{ref}).		
minimum	power and torque	$P_{ref} < 0\%$ (motoring).
minimum	power and speed	$f_{nref} = 0\%$ (idle) and $P_{ref} = 0\%$ (idle) and $P_{ref} - (2\% \cdot P_{max mapped}) < P < P_{ref} + (2\% \cdot P_{max mapped})$.
minimum	power and either torque or speed	$f_n > f_{nref}$ or $P > P_{ref}$ but not if $f_n > f_{nref}$ and $P > P_{ref}$.
maximum	power and either torque or speed	$f_n < f_{nref}$ or $P < P_{ref}$ but not if $f_n < f_{nref}$ and $P < P_{ref}$.

(f) *Statistical parameters.* Use the remaining points to calculate regression statistics described in § 1065.602. Round calculated regression statistics to the same number of significant digits as the criteria to which they are compared. Refer to Table 2 of § 1065.514 for the criteria. Calculate the following regression statistics :

(1) Slopes for feedback speed, $a_{f_{in}}$, feedback torque, a_{f_T} , and feedback power a_{f_P} .

(2) Intercepts for feedback speed, $a_{0f_{in}}$, feedback torque, a_{0f_T} , and feedback power a_{0f_P} .

(3) Standard estimates of error for feedback speed, $SEE_{f_{in}}$, feedback torque, SEE_{f_T} , and feedback power SEE_{f_P} .

(4) Coefficients of determination for feedback speed, $r^2_{f_{in}}$, feedback torque, $r^2_{f_T}$, and feedback power $r^2_{f_P}$.

(g) *Cycle-validation criteria.* Unless the standard-setting part specifies otherwise, use the following criteria to validate a duty cycle:

(1) For variable-speed engines, apply all the statistical criteria in Table 2 of this section.

(2) For constant-speed engines, apply only the statistical criteria for torque in the Table 2 of this section.

TABLE 2 OF § 1065.514—DEFAULT STATISTICAL CRITERIA FOR VALIDATING DUTY CYCLES

Parameter	Speed	Torque	Power
Slope, a_1	$0.950 \leq a_1 \leq 1.030$	$0.830 \leq a_1 \leq 1.030$	$0.830 \leq a_1 \leq 1.030$.
Absolute value of intercept, $ a_0 $	$\leq 10\%$ of warm idle	$\leq 2.0\%$ of maximum mapped torque.	$\leq 2.0\%$ of maximum mapped power.
Standard error of estimate, SEE	$\leq 5.0\%$ of maximum test speed.	$\leq 10\%$ of maximum mapped torque.	$\leq 10\%$ of maximum mapped power.
Coefficient of determination, r^2	≥ 0.970	≥ 0.850	≥ 0.910 .

§ 1065.520 Pre-test verification procedures and pre-test data collection.

(a) If your engine must comply with a PM standard, follow the procedures for PM sample preconditioning and tare weighing according to § 1065.590.

(b) Unless the standard-setting part specifies different values, verify that ambient conditions are within the following tolerances before the test:

(1) Ambient temperature of (20 to 30) °C.

(2) Atmospheric pressure of (80.000 to 103.325) kPa and within $\pm 5\%$ of the value recorded at the time of the last engine map.

(3) Dilution air as specified in § 1065.140(b).

(c) You may test engines at any intake-air humidity, and we may test engines at any intake-air humidity.

(d) Verify that auxiliary-work inputs and outputs are configured as they were during engine mapping, as described in § 1065.510(a).

(e) You may perform a final calibration of the speed, torque, and proportional-flow control systems, which may include performing practice duty cycles.

(f) You may perform the following recommended procedure to precondition sampling systems:

(1) Start the engine and use good engineering judgment to bring it to 100% torque at any speed above its peak-torque speed.

(2) Operate any dilution systems at their expected flow rates. Prevent aqueous condensation in the dilution systems.

(3) Operate any PM sampling systems at their expected flow rates.

(4) Sample PM for at least 10 min using any sample media. You may

change sample media during preconditioning. You may discard preconditioning samples without weighing them.

(5) You may purge any gaseous sampling systems during preconditioning.

(6) You may conduct calibrations or verifications on any idle equipment or analyzers during preconditioning.

(7) Proceed with the test sequence described in § 1065.530(a)(1).

(g) After the last practice or preconditioning cycle before an emission test, verify the amount of contamination in the HC sampling system as follows:

(1) Select the HC analyzer range for measuring the flow-weighted mean concentration expected at the HC standard.

(2) Zero the HC analyzer at the analyzer zero or sample port. Note that FID zero and span balance gases may be any combination of purified air or purified nitrogen that meets the specifications of § 1065.750. We recommend FID analyzer zero and span gases that contain approximately the flow-weighted mean concentration of O₂ expected during testing.

(3) Span the HC analyzer using span gas introduced at the analyzer span or sample port. Span on a carbon number basis of one (C₁). For example, if you use a C₃H₈ span gas of concentration 200 µmol/mol, span the FID to respond with a value of 600 µmol/mol.

(4) Overflow zero gas at the HC probe or into a fitting between the HC probe and its transfer line.

(5) Measure the HC concentration in the sampling system, as follows:

(i) For continuous sampling, record the mean HC concentration as overflow zero air flows.